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DERIVATION AND APPLICATION OF FORCE LIMITS FOR VIBRATION TESTS

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An improved vibration testing technique, which limits the force applied to the test item by the shaker, has been used successfully in ten JPL flight hardware tests during the past three years. For lightweight aerospace structures, the mechanical impedance of the test item and the flight mounting structure are typically comparable so that the combined motion involves modest interface forces and little amplification. Thus the high amplification resonances and associated failures which often occur in conventional vibration tests, with essentially unlimited force, are test artifacts which can be eliminated by limiting the force in the test to that predicted for flight. Input force limiting is in theory equivalent to response limiting, but force limiting is more convenient and less dependent on the details of test item models, implementation of force limiting involves: derivation of a force limit specification, installation of force transducers between the shaker and test item, and operation of the shaker with dual or extremal control of acceleration and force,

Derivation of Force Limits

There are essentially no flight data, and little system test data, on the forces at mounting structure and test item interfaces, Force limits are therefore derived using structural impedance, “effective mass”, data for mounting structures and test items. A new frequency shift method of deriving force limits will be described. The test item and mounting structure are each modeled in a limited frequency band as an oscillator with both modal and residual mass. The frequency shift when the oscillators are coupled is calculated and used to evaluate the peak in the

frequency response function of the coupled system force, given the peak acceleration which is identified with the conventional test specification. A tuning analysis then provides the force limit for vibration tests.

Applications of Force Limiting

The theory for the dual control of acceleration and force is based on Norton and Thevinen's equivalent circuit theorems. Both analytical and experimental methods of obtaining the mounting structure and test item effective mass will be described. Approaches to incorporating force transducers into the test fixturing will be described by way of example. Implementation of force limiting with older controllers which do not allow multiple references specifications will be discussed. Two of the JPL applications of force limiting will be described, one which used measured impedance data and one based on FEM analysis.

Finally, areas for additional research will be identified. Some of these are: validation and analysis of conservatism of force limiting, accelerance vs. effective mass measurements, multiple mounting point effective masses, moment specifications, and cross-axis specifications.